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REPORT

ON THE



P81

LOWESTOFT SAILING TRAWLER RECORDS,
1903-1906.

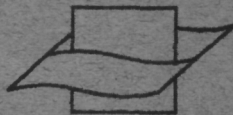
BY

ROSA M. LEE, M.A.,

Statistical Assistant on the Staff.

WITH FIGURES 1-4; TABLES I.-X.; APPENDIX I. AND ONE CHART.

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Vlaams Instituut voor de Zee
Flanders Marine Institute

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REPORT
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LOWESTOFT SAILING TRAWLER RECORDS, 1903-1906.

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I.—INTRODUCTION.

THE RECORDS AND THEIR TREATMENT.

This report is intended to furnish, as far as the material allows, a survey of the trawling grounds of the Southern North Sea, including only those parts that are fished by the Lowestoft smacksmen. With the exception of the records of four voyages made by four other skippers, all the material has been recorded by three skippers who fish regularly from Lowestoft. They were supplied with record books, in which they filled up all the particulars of each haul they made. Copies of the forms used in these books are given in the Appendix.

These have been regularly kept since the time they were commenced in April, 1903, and as the particulars of each haul are given in great detail, it is hoped that this will somewhat compensate for the disadvantages that arise from the fact that the regular records are those of only three men.

I take this opportunity at the outset, of acknowledging my indebtedness to my colleagues at the Lowestoft Laboratory, especially to Dr. Garstang, for his most valuable help at the commencement of my work, and to Dr. Allen and Mr. Borley for the many suggestions and criticisms they have made during the preparation of this paper.

The first problem to be dealt with in using this mass of statistical data was the finding of a method of reducing the material in such a way as to give the most reliable results. The object in view is to represent as simply and as accurately as possible, the fluctuations in abundance of some of the principal food fishes in the particular areas covered by the statistics. This first part of the report contains the analysis of the records of the two species, economically most important, plaice and soles.

The sources of error which are inevitably present in any such group of records must be sought for, and their influence eliminated as far as possible. The great amount of detail that is given makes it possible to do this to some extent. There is naturally a bias towards over or under estimation of the amounts by the fishermen, and it is possible to determine for each man in what direction this "personal equation" or "bias" lies, so that even though it may not be feasible to apply an accurate correction, yet we can attain some idea of the amount of this bias and of the reliability of the figures. However, remembering that the resulting figures will only be used for purposes of comparison and not as absolute measures, these biased errors by an important statistical principle, become relatively unimportant in the ratio of two estimates. It will be found that, though errors are present due to several sources, they are not enough to obscure the fluctuations in the figures produced by the seasonal influences.

THE GROUNDS TRAWLED AND DIVISION INTO AREAS.

The fishermen whose records are here examined, fish regularly in the Southern part of the North Sea, south of the line of latitude $53^{\circ} 30'$ and north of $51^{\circ} 30'$, and well within a radius of 80 miles from Lowestoft.

This area contains fishing grounds of very diverse characters, and for purposes of comparison of one part with another, has been sub-divided into nine smaller areas, the sub-division being based as far as possible on the natural distinctions of depths and the

nature of the bottom. Within each area the sea bottom is of very fairly uniform character in all cases except those of A, E and H.

These areas are :—

(i.) Three northern areas named A, B and C where comparatively little fishing is done except in the summer. These include the Cromer Grounds, the Leman Banks and the Brown Bank.

(ii.) The shallow ground, D, between the Norfolk and Suffolk Coast and the Deep Water, *i.e.* the Yarmouth and Lowestoft Flats.

(iii.) The deep water opposite Yarmouth and Lowestoft which is divided into two main portions, E the northern part, including Smith's Knoll and Knoll Deep, and the southern portion H, in which are Middle Deep and Gabbard Deep. In these areas the depths are 21 fathoms and over.

(iv.) Area F, on the east of the Deep Water, including Winterton Shoal, the lower part of the Brown Ridges, and a part of the Broad fourteens. Here the depth varies from 14 to 21 fathoms.

(v.) Area J, containing the Brown Ridges, Lowestoft Shoal and the edge of the Deep Water. The average depth is about 19 fathoms. Our statistics show that this locality is much frequented and well fished over.

(vi.) Lastly area M, embracing the Hinder, and Schouwen Grounds, and east of the Brown Ridges. The depth varies considerably in the different parts of this area.

The appended *Chart* shows the arrangement of these areas in the southern part of the North Sea.

TABULATION OF RECORDS.

In dealing with the records, each haul was allotted to its particular area as given by the data supplied by the fishermen. These positions are only approximate, as owing to the fact that the vessels are smacks, it is not easy for the men to give their exact distance from Lowestoft nor their true bearings to a point. When any discrepancies were found between the name of the fishing ground, bearings, distance, and depth furnished by the records, the depth was considered the most reliable datum and the position of the vessel was judged from that.

Any accident to the fishing gear, such as a rent net, or loss of trawl is noted by the fishermen in the record of the haul. All such hauls have been omitted from the statistics as not being comparable with other hauls made under ordinary conditions.

In tabulating the returns, each man's records were first dealt with alone. The catches of all hauls made in a month, with the number of hours fishing in each, were entered upon a sheet and classified according to areas. The total catches were then made up for each area month by month throughout the four years. Finally the total catches of the several vessels were amalgamated and reduced to a series of averages extending month by month over the whole period. In this series there were some gaps owing to the scarcity of fishing or total lack of it in certain areas, and it was necessary, in order to smooth the results and to arrive at some measure of the seasonal fluctuations, to put together the catches of each month from all the years and take their average, thus obtaining a general representative average for each monthly period.

TREATMENT OF THE TABULATED RECORDS.

The simplest average to calculate is that obtained by dividing the total amount of fish in each month by the number of hauls, giving an average amount *per haul*. This would certainly be the best method were it true that the duration of all hauls was approximately the same. But an examination of the figures shows that this is not the case and that great differences exist, the length of a haul being anything from three hours to 12 hours or even more. Moreover, one of the fishermen in particular was found to make hauls of a duration considerably exceeding the others. If we assume that the longer the duration of a haul, the greater is the amount of fish caught, which is true, other circumstances being the same, then it is evident that the inclusion with or exclusion of this man's catches from the others, would materially alter the average. Their reasons for long hauls of 9, 10 or 12 hours' duration do not seem to be due to any generally accepted principle of action, but to a variety of motives, of which perhaps that of saving the time of hauling is the chief. Shorter hauls were made over muddy, and muddy and sandy bottoms than on sandy grounds.

It was at first thought that the duration of the hauls was protracted when there was little or no wind in order that the smacks might trawl over as much ground as would be covered in a shorter haul with an ordinary wind, and since in such a haul the catch per hour is naturally less than that which would be obtained were the vessel moving faster with a fresh wind, it was considered that the average per haul would give a better result than the catch per uniform time. This theory was tested by an examination of the figures, which did not at all bear out the idea that the duration of the haul was correlated to the force of the wind. Indeed it was found that long hauls went as often with strong winds as with no wind, and short hauls as often with no wind as with strong winds.

The correlation co-efficient between the two in the records for one year, was calculated and was found to be $-.01$. This shows definitely that there is no correlation, and it is clear that the duration of the hauls depends on causes which together far exceed in importance the strength of the wind; and one comes to the conclusion that it will not do to allow that all lengthy hauls are but efforts on the fishermen's part to make up in time what they have lost in distance trawled through lack of wind.

From these considerations it is evident that the only figures which will be comparable are those averages that are based on a uniform time of fishing. The most usual duration of a haul is six hours (corresponding to the duration of a tide), and this has been selected as the unit so that all averages are calculated per six hours' fishing.

The following table (Table I.) gives the total number of hauls and of hours fishing made by each man in each year, and brings out the difference in the average duration of their hauls.

TABLE I.—Showing for each of three fishermen, the total number of hauls and hours fishing, and the average duration of a haul.

	Skipper.	1903. April-Dec.	1904.	1905.	1906.
Number of hauls ...	i	310	376	423	465
	ii	253	385	378	388
	iii	330	485	479	522
	All.	893	1,246	1,280	1,375
Number of hours fishing ...	i	1778 $\frac{1}{2}$	2,350	2,585	2,892 $\frac{1}{2}$
	ii	2234 $\frac{1}{4}$	3,217 $\frac{1}{2}$	2,972 $\frac{3}{4}$	2,835 $\frac{1}{4}$
	iii	1965	3,138	2,778 $\frac{3}{4}$	2,997 $\frac{1}{2}$
	All.	5977 $\frac{3}{4}$	8,705 $\frac{1}{2}$	8,336 $\frac{1}{2}$	8,725 $\frac{1}{4}$
Average duration of haul in hours.	i	5.74	6.25	6.11	6.22
	ii	8.83	8.36	7.87	7.31
	iii	5.95	6.47	5.80	5.74
	All.	6.69	6.99	6.51	6.35

N.B.—This table does not include the hauls in which the net was rent nor the few hauls recorded by the other fishermen in 1903 and 1904.

DISTRIBUTION OF THE FISHING OVER THE AREAS INVESTIGATED.

Table II. has been drawn up to show how the fishing has been distributed in the various parts of our region. It gives the total number of hours fishing in each area and the percentage that this forms of the whole amount of fishing in each year. We find that a very small proportion of the whole fishing occurs in A, B, C and D, and that E, F, H, J and M share between them and nearly equally the greater part of the rest.

There is no very great change in the distribution of the fishing from year to year, and for this reason it was thought justifiable to combine the totals from all areas and form yearly averages for all species, which would be fairly comparable and not unduly biased by unequal distribution in well-stocked or ill-stocked areas. The amount of fishing in A, B, C and D is so small that the variations in these will not much affect a general average, while the variations in the other and more important areas and their effects will be discussed with respect to the yearly averages of the several species.

TABLE II.—Showing the total yearly amounts of fishing in each area in hours, and the percentages of the total number of hours fishing occurring in each area in each year.

Area.					1903.	1904.	1905.	1906.	1903-6.
A	{	Hours	...	...	55	66	125½	79	325½
...		Percentage	...	...	0·9	0·7	1·5	0·9	1·0
B	{	Hours	...	...	414½	507½	256½	85	1,263½
...		Percentage	...	...	6·7	5·4	3·1	1·0	3·9
C	{	Hours	...	...	146½	166	35	15	362½
...		Percentage	...	...	2·4	1·8	0·4	0·2	1·1
D	{	Hours	...	...	154	37	268½	274	733½
...		Percentage	...	...	2·5	0·4	3·2	3·1	2·2
E	{	Hours	...	...	1,708	1,711	1,579	1,403½	6,401½
...		Percentage	...	...	27·7	18·2	18·9	16·1	19·6
F	{	Hours	...	...	1,532¾	1,788½	1,359½	1,070½	5,751¼
...		Percentage	...	...	24·8	19·0	16·3	12·3	17·6
H	{	Hours	...	...	1,042½	1,714¾	1,470¼	1,622¼	5,849¾
...		Percentage	...	...	16·9	18·3	17·6	18·6	17·9
J	{	Hours	...	...	834½	1,882¾	1,749	2,045½	6,511½
...		Percentage	...	...	13·5	20·0	21·0	23·4	20·0
M	{	Hours	...	...	285¾	1,520	1,493½	2,130½	5,429¾
...		Percentage	...	...	4·6	16·2	17·9	24·4	16·6
Total					6,173¼	9,393½	8,336½	8,725¼	32,628½

II.—ACCOUNT OF SEPARATE SPECIES.

A.—PLAICE.

Unreliability of Fishermen's Estimates with regard to Size Distinctions.

In the Record forms the amounts of large, medium and small size plaice are given separately, and in tabulating, these distinctions were first kept. But it soon became evident that these distinctions introduced a source of error and that one man's estimates were not comparable with another's. In some cases the plaice would be divided into only two groups, large and small, while another man would record his plaice taken at the same time from the same area as medium and small. Moreover they were not consistent in this, and would occasionally change their method of classification. The result was that instead of the large, medium and small fish forming approximately the same proportion of the total catch, for each of the three men, as one would expect them to do when they fish in the same areas under the same conditions, and the average of a large number of hauls is taken, a great difference was found in their various estimates.

The following table illustrates this point. It represents the average catch in cwts. per six hours' fishing in the area F, during the three summer months of 1904. The average weights of the different size groups are very different, but the weights of the whole catch are very nearly equal in the three men :—

TABLE III.—Showing the average catch in cwts. obtained per six hours' fishing by three Skippers in area F, during July to September, 1904 :—

					Skipper.		
					i.	ii.	iii.
Large	...	...	...	...	·27	—	·17
Medium	...	...	...	...	·59	·65	·82
Small	...	...	...	...	·09	·52	·11
Total weight					·95	1·17	1·10

SIZE OF PLAICE.

The estimated average lengths of large, medium and small plaice are $17\frac{3}{4}$ inches, 13 inches and $9\frac{3}{4}$ inches respectively. When questioned on this matter two of the men said that they reckoned a fish of 12 or 13 inches in length to be of *medium* size, but the other takes as *large plaice* those of 12 inches and over, while *medium* are about nine inches, and *small* eight inches and under on the average.

Seeing that so much diversity of opinion on this matter of size exists, and that in each haul the proportion which the large, medium and small fish form of the total catch, must of necessity be but rough estimates, it becomes evident that in these cases the size distinctions are unreliable and that better results will be obtained by grouping all sizes together.

The totals and averages given in the tables represent only the actual amounts of plaice landed. In many cases a great number of small plaice unfit for market were caught in the trawl and afterwards thrown overboard. The amounts of these were sometimes given, but the information supplied about the unmarketable fish was too uncertain and indefinite for any numerical measure of the proportion they formed of the catch to be obtained. In what follows, marketable plaice alone are discussed.

Reduction of Data to a Uniform Standard.

The amounts of plaice are given in one of the three following ways :—(i) Number of boxes or trunks, (ii) Number of baskets, and (iii) Number of fish.

The measuring of the fish in trunks was carried out only in 1903 and the early part of 1904, when the Record Books were of a slightly different form. It was given up in April 1904 owing to the confusion caused by the fishermen using this term in different senses.

The 'baskets' were adopted as the unit in 1904. The numbers of the fish are only given when they are too few to be measured by a basket. To obtain an average it is necessary to reduce these measurements to one and the same unit. Enquiries were made at the fishmarket, and from information supplied by the salesmen, the following were taken as the average equivalents of the different measures :—

2 Baskets = 1 Market Trunk or Box.
1 Trunk of Plaice weighs 1 cwt.

The average numbers of large, medium and small plaice which go to fill a trunk were also found, but as all sizes were being put together, the simplest method of reduction was to give the total estimated weight in cwts., taking 1 basket = $\cdot 5$ cwt.

When the numbers of the fish were given they were reduced to weight by the following approximate scale, which has been calculated from the curve showing the weight of plaice according to size obtained from tables prepared by the Board of Agriculture and Fisheries* :—

Size of Plaice.					Length.	Weight.
Large	...	...	...	...	$17\frac{3}{4}$ inches.	$\cdot 02$ cwts. = 35 ozs.
Medium	...	...	...	...	13 "	$\cdot 007$ " = $12\frac{1}{2}$ "
Small	...	...	...	...	$9\frac{3}{4}$ "	$\cdot 003$ " = 5 "

The proportion of fish recorded in numbers is very small, so that the error introduced by using the weights on the fishermen's somewhat unreliable classification will not be serious.

The records for 1903 had to be treated differently from the other years owing to the different interpretations of the 'trunk' unit employed by the fishermen.

* Report of the Select Committee of the House of Lords on the Sea Fisheries Bill, London, 1904, p. 80.

One skipper (No. ii) informed us that he measured his fish in baskets and estimated the equivalent number of market trunks to put down in his records, so that in converting his amounts we have taken 1 trunk=1 cwt. But the other fishermen stated that they had recorded their catches in 'level' trunks, so that six trunks or boxes in their records are equivalent to four market trunks. Adopting this explanation, the weight of one of these trunks was taken as $2/3 = .67$ cwt.

That these corrections are in the right direction will be seen in Table 5, where in 1903 the average for the year in the case of fisherman (No. ii) is less than those of the other two, so that there has been clearly no over-estimation in taking his 'trunks' to be heavier than those of the others.

On the other hand it is improbable that the records of the other two fishermen have been under-estimated, not only because their own estimate of the relation between 'market' and 'level' trunks has been adopted, but also because, if one neglects their explanations and treats their 'trunks' as market trunks, the resultant average catches for 1903 become raised to amounts which are extraordinarily higher than those for the other years, a fact which points at once to the existence of some biased error.

Measure of Bias.

Since April 1904 there has been included in each Record Book a page for the summary of the voyage. On this the skipper records the total quantity of fish landed as it is packed ready for market. This is a fairly accurate measure and affords a valuable test of the accuracy of the estimates made for each individual haul. By adding up the total number of baskets of plaice caught in all the hauls of a voyage, and making an estimate for the baskets equivalent to the number of fish caught when these are given, we can compare these totals with the summaries by taking two baskets = 1 trunk.

This has been done for each skipper and the results are somewhat interesting. There are a few instances where these totals of individual records are twice or one and half times the amounts given in the summary of the voyages, thus showing a great over-estimation. Many of the totals slightly exceed the summary totals by one or two boxes on totals of from 12 to 20 boxes in the voyage, while others are just as much in defect. The following are a few instances taken at random and they will illustrate the nature of the correspondence between the two :—

Number of boxes given in the Summary of each voyage.		Total number of boxes estimated from the Separate Records.	
16	...	17	
23	...	$25\frac{1}{4}$	
20	...	$25\frac{1}{4}$	
$20\frac{1}{2}$	...	$23\frac{1}{4}$	
8	...	$7\frac{3}{4}$	
$6\frac{1}{2}$	...	$5\frac{1}{4}$	
$10\frac{1}{2}$	...	11	
4	...	3	
11	...	$15\frac{1}{2}$	
13	...	$19\frac{1}{2}$	

In order to see whether in the long run the tendency is to over- or under-estimate, the average ratios of the totals to the summaries have been calculated for each year and for each fisherman. They are given by the following table with their probable errors :—

TABLE IV.—Showing the relation between the Totals and Summaries for each Skipper, throughout the period.

Skipper.			1904.	1905.	1906.	Average ratio.
(i)	...	...	$1.17 \pm .01$	$1.04 \pm .01$	$1.01 \pm .02$	1.07
(ii)	...	...	$0.92 \pm .01$	$0.87 \pm .01$	$0.88 \pm .01$	0.89
(iii)	...	...	$1.24 \pm .03$	$1.18 \pm .04$	$1.07 \pm .02$	1.16
All	...	...	$1.11 \pm .01$	$1.03 \pm .01$	$0.99 \pm .01$	1.04

From this table we gather that Skipper (i) has a tendency to over-estimate his amounts to the extent of about 7 per cent. on the average per voyage. Skipper (ii) under-estimates by a little over 10 per cent. on the average, while Skipper (iii) has by far the largest bias, as much as 24 per cent. in 1904, and as 16 per cent. when the three years are taken together. The probable errors given in the table show that this man has a greater variation in his ratios than the others. Taking the average of the ratios of the three men we see that there is a slight over-estimation in the long run, the totals of the individual records exceeding the amounts given in the summaries by about 4 per cent.

It has been impossible to apply corrections for this bias in the monthly averages for each area, owing to the fact that the hauls in one voyage may be distributed over several areas and their error may diverge to a considerable extent from the average ratio given in the table. But in the long run when we have averages based on a considerable number of hours fishing, these tendencies to excess or defect will nearly balance one another. The apparent irregularity in some of the monthly averages can be accounted for to some extent by the presence of these biased errors especially in cases where there is little fishing, and where one man's returns preponderate over the others.

Yearly Variations in the Amount of Plaice.

Before dealing with the monthly averages for each separate area we can treat the fishing grounds as one whole area representing the Southern part of the North Sea and find how the amounts fluctuate from year to year by working out the average per six hours fishing for each year. In such averages as these, based on a whole year's fishing over approximately the same ground, which too is a comparatively small region and does not show a very large range of difference between its several parts, we do not expect to find much difference in the average figures of the three fishermen unless they are influenced by biased errors.

The following Table shows in cwts. year by year, for each fisherman, the total catch of plaice, the average per haul, and the average per six hours fishing. It will be noticed that the latter averages are far more uniform than the former :—

TABLE V.—Showing in each year the total weight of Plaice in cwts., the average weight per haul and the average weight per 6 hours fishing taken by each skipper.

—	Skipper.	April-Dec., 1903.	1904.	1905.	1906.
Total weight of Plaice in cwts. {	i	342·6	432·07	440·01	460·28
	ii	401·85	559·30	509·09	456·41
	iii	432·50	659·14	437·05	413·24
	All	1176·91	1650·51	1386·15	1329·93
Average weight of Plaice per haul {	i	1·10	1·15	1·04	0·99
	ii	1·59	1·45	1·35	1·18
	iii	1·31	1·36	0·91	0·79
	All	1·32	1·32	1·08	0·97
Average weight of Plaice per 6 hours fishing {	i	1·16	1·10	1·02	0·95
	ii	1·08	1·04	1·03	0·97
	iii	1·32	1·26	0·94	0·83
	All	1·18	1·14	1·00	0·91

This is a very instructive table. The averages per haul show the great excess in the catches of fisherman ii. over those of the others, owing to the lengthy duration of his hauls. This difference is corrected in the six-hourly averages, but we notice here that fisherman ii's. averages in 1903 and 1904 are below those of i. and iii. Probably this is due to the fact that he underestimates his amounts as a rule, while the others have the opposite tendency.

One of the most striking features of the table is the continued decline evidenced in the figures throughout the four years, and this is shown, not only by the averages of all

the fishing but by each man separately. The following diagram shows this decline graphically.

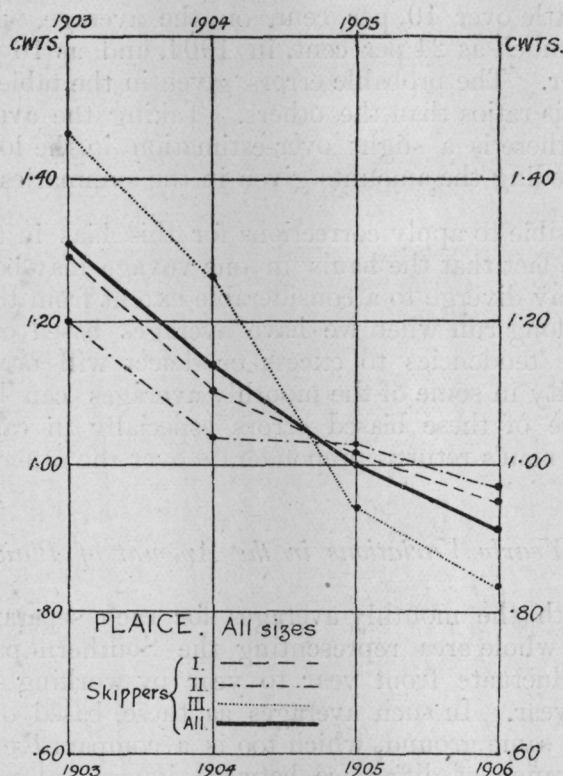


FIG. 1.—Curves showing the annual average catch of plaice in cwts. per 6 hours fishing by each of the three skippers and by all together.

We notice that the values for 1903 on this curve are different from those in the table which do not show any marked excess over the figures for 1904. This difference is due to the fact that 1.31 cwts. is the value estimated for the whole of 1903, whereas the value in the table, 1.18, is the average of the records from April, 1903, when they were started, to December. The average for the first three months of the year is higher than for the remaining months, and the omission of these in our yearly average considerably lowers the resulting figure. A correction was obtained as follows:—Taking the years 1904, 1905 and 1906 together, the average for the first three months is 1.31 cwts., for the last nine months it is 0.92 cwts., and for the year it is 1.02. Multiplying 1.18, the average for the nine months of 1903 by the factor $\frac{1.02}{0.92}$ we obtain 1.31 cwts. as the probable average for the whole of 1903. The figures 1.29, 1.20 and 1.46 the corrected averages for the individual fishermen were obtained in a similar way.

In order to test this decline still further, the 'probable difference' between the averages for any two years, that is, the amount of difference which is expected to come by chance, has been determined. This has been done by the formula $r = r_1 \sqrt{\frac{1}{N_1} + \frac{1}{N_2}}$, where r_1 is the probable error of the whole group and N_1 and N_2 the numbers which enter into the averages to be compared. These probable differences are:—

Between 1903 and 1904	...	...	...	...	0.024 cwts.
„ 1904 and 1905	...	...	...	...	0.022 „
„ 1905 and 1906	...	...	...	...	0.021 „

These differences are as likely to occur as not; a difference of greater than $2r$. would arise once in 6 times and of $4r$. once only in 160 times. Taking the estimated figures for 1903 the differences are .17, .14 and .09 respectively, all of which are real differences and very significant. Even if these averages were reduced by the measure of bias given in Table IV. on page 96, when they would become the following:—1904, 1.03; 1905, 0.97; 1906, 0.92, the differences are still significant although their magnitude is less. With reference to the table on page 94, Table II., we see that J and M have a slightly increasing amount of fishing from 1903–1906. These will later be shown to be the best stocked areas. On the other hand, E and F, which have a smaller stock of plaice, become less and less fished throughout the period. The effect therefore of this

difference of distribution of the fishing is to have *raised* the true values in the later years, so that the decline in the later years cannot be shown to be due to the fact that more of the fishing has taken place in naturally less populated areas.

We have thus established the fact that there has been a marked and steady decline in the average amount of fish taken during the period. Unfortunately these statistics do not enable us to determine what is the cause of this apparent decline—whether it arises from a real decrease in the stock of plaice in the sea—or from some other causes. Nor, if the former is the case, can we tell whether the decline is a permanent one and will continue, or whether in the later years of this period we have simply evidenced one or two slack seasons after a period of great abundance. Further observations over a considerable number of years will be necessary to establish these points. In the meantime these figures may be valuable in corroborating or otherwise the evidence gathered from similar statistics.

Distribution and Seasonal Variations.

The following table (Table VI.) gives for each of the nine areas the average catch of plaice per six hours fishing month by month throughout the period 1903–1906. To show the seasonal fluctuations, the averages of the catches of all the Januaries, all the Februaries, &c., have been calculated and shown in thick type. As the reliability of an average is proportional to the number of hours fishing on which it is based, it was thought best to use weighted averages. The method of procedure was as follows:—The total catches of all the Januaries were added together, and the sum divided by the number of six-hours periods in the total number of hours fishing in all the Januaries, and so for the other months. This method gives a 'weighted' average, most weight being placed on the catch of that year in which there is most fishing in this month. These figures are plotted out as continuous curves and give a graphic representation of the seasonal variations (Fig. 2).*

The table shows that the records are in many places incomplete, and for this reason it is not possible to represent the seasonal variations by plotting out the monthly averages for each year separately. In studying the figures and in making deductions from them, it will be necessary to bear this fact in mind and not to put too much reliance on them if, as is several times the case, the general average is not fairly representative of at least three years' fishing, or is perhaps based on the total catch of a very few hauls. The probable error of any average varies inversely as the square root of the number of 6 hours hauls in that average, so that the greater the number of hauls the greater is the reliability of the average. The probable error of any one haul of 6 hours' duration is approximately .5 cwt. These probable errors of the averages have been calculated in several cases, and the general averages which, for any of the reasons mentioned above, are found to be obviously unreliable are put in square brackets in the table.

In comparing one month with another we must be careful to note whether an increase in the general average is also shown in the averages for all the years separately or whether it is mainly due to an excessively high average in any one particular year. In area H. the average for August is 0.73, a large increase on 0.49 cwts. in July. This is due to the high average 1.39 in 1903. The averages for 1904, 1905, and 1906 do not show any significant increase on those of July for the same years. We conclude therefore that the apparent increase in August is misleading.

Looking now at the diagrams (Fig. 2) we see several general facts brought out very clearly. There is no fishing during the winter on the Northern areas A, B, C, apparently because at this time the fish are more plentiful further south. A small amount is caught in spring and this increases rapidly, maintaining a fairly high level throughout the summer and early autumn when the quantity suddenly falls. From the diagrams it is evident that the greatest average weight of plaice comes from area M, the Hinder and Schouwen grounds. This is probably due to the large number of small plaice which form a great portion of the catch. The next in total amount seems to be J, the Brown Ridges, the area immediately north of M. The next northerly area F, has a little less.

Of the deep areas, H the most southerly has the greater amount of fish, especially from December to February. On E, about Smith's Knoll, few fish are caught, but these are mostly large and medium plaice, and for this reason the catches from this area are more valuable in proportion to their bulk than are those from some of the more southerly areas.

* Broken lines are used in the diagrams to join two alternate months' averages, when there is no record in the intermediate month. Thin lines are used to join up averages of months, which are considered unreliable.

TABLE VI.—Showing for each area the monthly average catch of Plaice in cwts by an index

Area.	Year.	January.	February.	March.	April.	May.	June.
A	1903	—	—	—	—	—	0.25 ¹⁷
	1904	—	—	—	—	—	—
	1905	—	—	0.08 ²⁵	0.26 ⁴⁴	—	0.10 ⁵⁵
	1906	—	—	—	0.03 ¹⁶	0.03 ⁶³	—
	1903-6	—	—	[0.08] ²⁵	[0.20] ⁶⁰	[0.03] ⁶³	[0.13] ⁷²
B	1903	—	—	—	0.78 ³⁶	0.98 ¹³⁵	1.02 ¹³⁸
	1904	—	—	—	—	—	0.94 ³²⁴
	1905	—	—	0.09 ⁴	—	—	0.46 ⁹⁸
	1906	—	—	—	—	—	—
	1903-6	—	—	[0.09] ⁴	[0.78] ³⁶	[0.98] ¹³⁵	[0.86] ⁴⁷⁰
C	1903	—	—	—	—	0.34 ⁷	1.51 ²³
	1904	—	—	—	—	—	1.25 ⁴²
	1905	—	—	—	—	—	0.67 ¹⁸
	1906	—	—	—	—	—	—
	1903-6	—	—	—	—	[0.34] ⁷	[1.21] ⁸⁵
D	1903	—	—	—	—	0.20 ⁴⁶	0.37 ⁶
	1904	—	—	—	—	—	0.11 ¹²
	1905	—	—	0.27 ¹²	—	+ ⁵⁷	0.05 ³⁴
	1906	0.24 ³⁰	—	—	0.02 ¹²	0.01 ⁵	—
	1903-6	[0.24] ³⁰	—	[0.27] ¹²	[0.02] ¹²	[0.09] ¹⁰⁹	[0.17] ²¹
E	1903	—	—	—	—	0.25 ⁴⁶	0.90 ¹⁸³
	1904	2.09 ⁶	0.80 ⁶⁵	—	—	—	0.85 ²⁴⁵
	1905	0.73 ³⁰	0.63 ⁴⁴	1.09 ²²	0.35 ²⁹	0.51 ³¹	0.40 ¹⁸²
	1906	—	0.54 ²³	0.08 ²²	0.08 ⁵	0.24 ¹⁸	0.40 ⁶
	1903-6	[0.95] ³⁵	0.68 ¹⁸²	0.58 ⁴⁴	0.31 ³⁴	0.33 ⁹⁵	0.73 ⁶¹⁶
F	1903	—	—	—	1.59 ⁹⁶	1.95 ¹⁶⁸	1.45 ²⁴⁰
	1904	1.33 ⁹⁶	0.77 ⁷⁷	1.43 ¹⁰	—	0.95 ⁹	0.91 ²⁹³
	1905	—	0.75 ¹²	0.78 ⁷⁸	1.06 ³	0.46 ⁶³	0.73 ³⁰⁵
	1906	—	0.55 ²²	0.51 ⁵⁰	0.65 ¹⁷⁵	1.04 ¹²⁹	0.55 ⁸⁹
	1903-6	[1.33] ⁹⁶	0.72 ¹¹¹	0.74 ¹³⁹	0.99 ³⁰⁶	1.29 ⁴²⁷	0.96 ⁹²⁸
H	1903	—	—	—	0.87 ²⁰	0.79 ⁵⁰	1.15 ⁷⁰
	1904	1.24 ⁵⁷⁹	1.41 ²⁵⁶	1.17 ⁶	—	0.17 ⁵	0.35 ¹¹⁹
	1905	1.45 ⁴²¹	1.55 ⁴⁴⁴	—	1.00 ⁶	1.70 ²³	0.81 ¹²
	1906	1.19 ³¹⁶	0.96 ³⁰⁹	0.37 ⁴²	—	0.17 ¹⁰	0.26 ¹⁹
	1903-6	1.30 ¹³¹⁶	1.30 ¹⁰⁹⁹	[0.47] ⁴⁸	0.90 ²⁰	0.93 ⁸⁹	0.62 ²²⁰
J	1903	—	—	—	1.66 ¹⁶²	1.61 ²¹⁶	1.49 ⁷⁶
	1904	1.08 ²⁴⁷	1.42 ²⁷⁹	1.84 ⁹³	1.70 ³⁹³	1.02 ²⁹⁸	1.04 ⁴⁹
	1905	1.57 ⁶⁰	1.30 ¹¹⁸	1.34 ⁵⁵	1.79 ²³¹	1.33 ³⁸¹	1.15 ⁹¹
	1906	1.37 ¹⁸	1.04 ⁹⁷	1.00 ¹³⁸	1.08 ³²⁷	0.90 ³⁰⁷	0.66 ³³⁵
	1903-6	1.19 ³²⁵	1.32 ⁴⁰⁵	1.34 ²⁸⁰	1.52 ¹¹¹⁴	1.19 ¹¹⁹⁸	0.89 ⁵⁵¹
M	1903	—	—	—	1.13 ⁴²	2.53 ¹⁹	1.42 ²⁹
	1904	1.57 ¹⁹⁶	1.20 ¹⁶⁴	1.71 ¹⁶⁶	1.67 ²³⁶	1.43 ⁴⁵⁵	0.78 ⁴⁰
	1905	1.69 ²⁶⁹	1.06 ⁸¹	1.71 ²²²	1.44 ³¹⁸	1.13 ¹⁹⁸	0.98 ⁵¹
	1906	1.37 ³⁸³	1.28 ²³¹	1.54 ⁵⁸⁹	1.33 ²⁴⁸	1.06 ¹⁹⁷	0.99 ¹³³
	1903-6	1.52 ⁸⁴⁹	1.23 ⁴²⁶	1.61 ⁹⁷⁷	1.46 ⁸⁴⁵	1.30 ⁸⁷⁰	1.00 ²⁵⁴

per six hours fishing. The number of hours fishing in each average is represented number.

July.	August.	September.	October.	November.	December.	Area.
—	0.93 ³⁸	—	—	—	—	A.
—	0.56 ⁶	0.43 ⁶⁰	—	—	—	
—	—	—	—	—	—	
—	—	—	—	—	—	
—	[0.88] ⁴⁴	[0.43] ⁶⁰	—	—	—	
1.73 ^{28½}	1.07 ⁶⁰	1.82 ¹¹	0.55 ^{5½}	—	—	B.
0.75 ⁷	—	1.05 ¹⁵⁶	0.67 ^{63½}	0.59 ^{46½}	—	
—	0.77 ^{32½}	1.31 ⁴⁵	0.83 ²³	0.60 ³⁴	—	
0.46 ⁶⁸	—	—	0.19 ⁵	0.62 ¹²	—	
0.83 ^{103½}	0.93 ^{112½}	1.15 ²¹²	0.68 ⁹⁷	0.60 ^{92½}	—	
0.87 ^{18½}	1.46 ^{20½}	1.37 ^{10½}	0.47 ⁵⁵	—	—	C.
—	—	—	2.22 ²³	1.30 ¹⁰¹	—	
—	—	—	1.09 ¹¹	1.37 ⁶	—	
—	—	0.64 ¹⁵	—	—	—	
[0.87] ^{18½}	[1.46] ^{20½}	[0.94] ^{25½}	1.00 ⁸⁹	1.30 ¹⁰⁷	—	
0.51 ^{19½}	—	—	0.31 ^{38½}	0.31 ⁴⁴	—	D.
—	— ⁵	0.03 ⁶	—	— ¹¹	0.48 ³	
0.09 ^{160½}	—	0.05 ^{11½}	—	0.10 ²³	—	
0.12 ³⁷	0.39 ⁹	0.02 ³	0.08 ³⁶	0.14 ^{93½}	—	
0.13 ^{215½}	[0.25] ¹⁴	[0.04] ^{20½}	0.15 ^{124½}	0.17 ^{171½}	[0.48] ³	
0.70 ⁴⁰⁷	0.92 ^{451½}	1.00 ^{436½}	1.42 ^{116½}	1.17 ⁶¹	1.33 ⁶	E.
0.49 ^{619½}	0.82 ^{454½}	0.91 ^{275½}	1.42 ^{20½}	—	0.58 ^{18½}	
0.33 ³⁹⁹	0.52 ^{511½}	0.59 ^{242½}	0.50 ⁶	0.36 ¹⁰	0.41 ⁷²	
0.33 ^{466½}	0.56 ⁴⁶⁷	0.49 ^{312½}	0.63 ³⁰	0.48 ³³	—	
0.46 ¹⁸⁰²	0.70 ^{188½}	0.78 ^{1266½}	1.26 ¹⁷⁹	0.81 ¹²⁴	[0.50] ^{96½}	
1.12 ^{194½}	1.15 ^{165½}	1.41 ^{226½}	1.33 ^{245½}	1.80 ^{191½}	3.36 ⁶	F.
0.82 ¹⁵⁶	1.11 ²⁷⁶	1.34 ²³⁰	1.33 ²⁸⁰	1.30 ²⁷¹	1.06 ^{29½}	
0.48 ^{109½}	0.71 ^{249½}	0.90 ¹⁵⁹	1.13 ^{166½}	1.19 ¹⁵⁰	0.71 ³²	
0.73 ⁷¹	0.91 ⁸³	1.04 ¹⁸²	1.31 ^{195½}	1.62 ^{67½}	1.00 ⁶	
0.85 ^{531½}	0.97 ^{773½}	1.20 ^{797½}	1.29 ^{887½}	1.45 ^{680½}	1.09 ^{73½}	
0.49 ²⁶	1.39 ^{24½}	1.02 ³¹	1.20 ^{189½}	0.93 ^{206½}	1.06 ⁴⁷⁴	H.
0.22 ⁸⁷	0.25 ⁶	0.38 ³³	0.12 ^{4½}	0.62 ⁶⁶	0.92 ^{552½}	
0.90 ¹⁰	1.00 ⁶	0.09 ⁴	0.68 ¹²	0.52 ^{309½}	0.82 ^{221½}	
0.72 ^{81½}	0.46 ⁵⁵	0.11 ³³	0.43 ^{96½}	0.55 ²⁴⁵	1.04 ^{224½}	
0.49 ^{204½}	[0.73] ^{91½}	0.48 ¹⁰¹	0.86 ^{252½}	0.64 ^{826½}	0.97 ¹⁵⁷³	
1.33 ⁶	—	1.20 ³⁶	1.18 ^{102½}	1.42 ²¹⁵	2.31 ¹⁹	J.
—	—	1.36 ⁴⁴	1.17 ^{162½}	1.34 ^{268½}	0.87 ⁵²	
0.77 ¹²³	—	1.25 ¹⁸⁵	1.72 ^{276½}	1.15 ¹⁸⁵	0.47 ⁴²	
—	0.97 ^{172½}	0.57 ³⁹	1.30 ^{357½}	1.00 ²⁰²	0.89 ³²	
0.80 ¹²⁹	0.97 ^{172½}	1.14 ³²⁴	1.39 ⁸⁹⁹	1.24 ^{870½}	0.95 ¹⁴⁵	
—	1.77 ²⁴	—	—	2.10 ¹⁰⁷	1.13 ^{63½}	M.
—	—	1.42 ¹⁸	1.71 ²⁸	1.91 ^{141½}	1.02 ⁷³	
0.40 ^{24½}	—	1.07 ¹⁴	1.60 ^{128½}	1.64 ⁷⁹	0.80 ^{137½}	
—	—	—	1.36 ⁷⁵	1.20 ^{84½}	1.29 ¹⁸⁹	
[0.40] ^{24½}	[1.77] ²⁴	[1.27] ³²	1.53 ^{231½}	1.76 ⁴¹²	1.07 ^{483½}	

The western area D, the Flats outside Lowestoft and Yarmouth, produces very little plaice, and is frequented by the fishermen mainly for soles. The fluctuations in this area are very irregular. In fact there is not enough fishing done here to give fair representative averages which make the months comparable with one another, and the only fact of importance shown by this curve is that of the scarcity of plaice.

Turning to the Knoll Deep area E, we find a well defined maximum in October which is significantly higher than September and November. The figures for December and January are incomplete and we cannot say that there is another maximum in January. There is probably a gradual fall from October continuing through the winter to a minimum in the spring months when the curve commences to rise again. This October maximum coming as it does a month or two later than the maximum period in the Northern areas is probably to be accounted for by a southward migration of fish from the Leman Banks and the adjacent grounds. There is evidence of a minor maximum in June as the fall of .27 cwts. to July is significant, being more than 5 times the probable difference .05.

The second of the Deep Water areas H, exhibits somewhat similar features, but the phenomena shown on the curve for area E take place at a later season in area H. The maximum period of abundance is apparently in January or February after which there is a falling off to a minimum in the summer and then a gradual rise.

The great fluctuations shown on the curve giving cusps in March, September and October are almost wholly due to the absence of sufficient records. The value 0.47 for March is evidently erroneous. Each of the September averages represents the catch of very few hauls, which fact probably accounts for the small value for that month.

There is not enough evidence to establish a maximum in October as the high value for that month is mainly due to the value 1.20 for the year 1903 which contributes the greatest share of the hauls in the general average. Two of the years show a decline from October to November and two a rise.

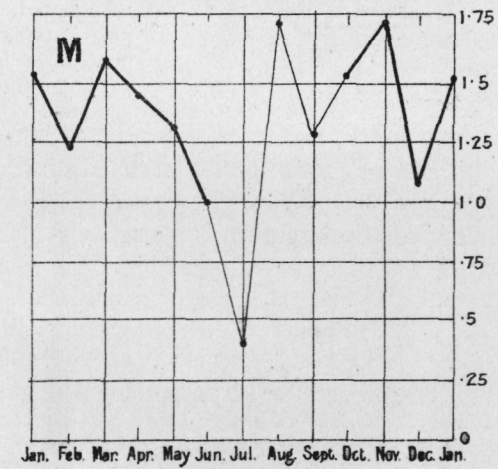
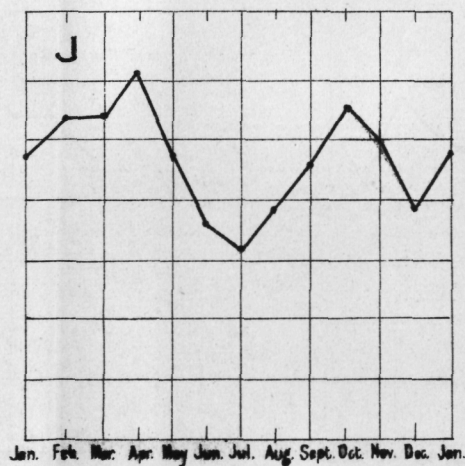
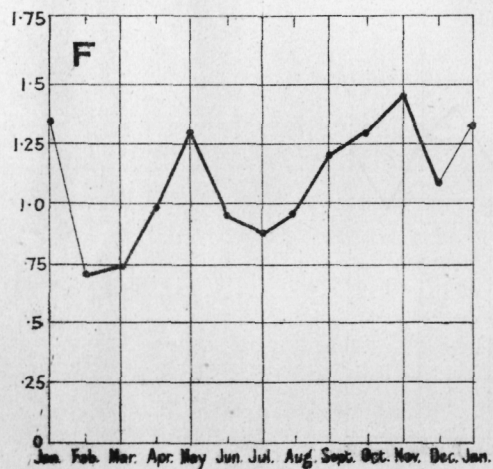
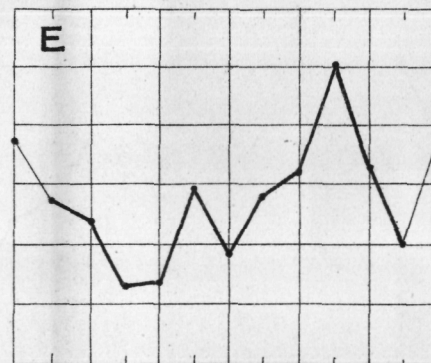
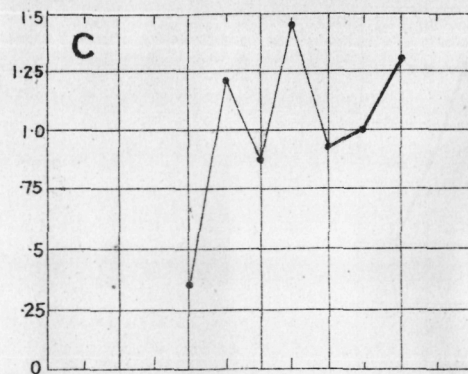
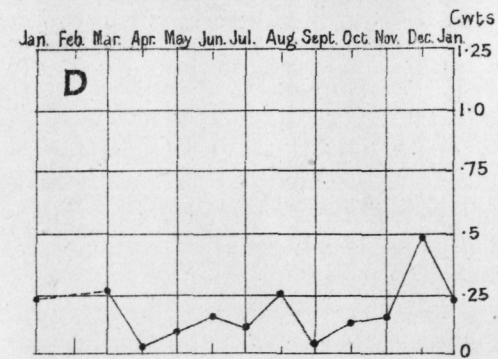
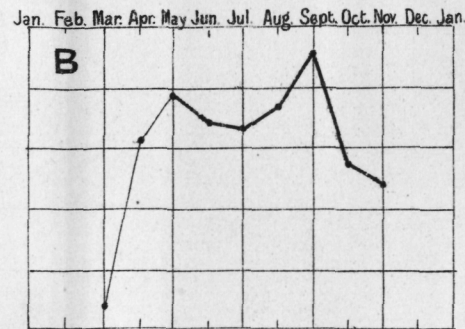
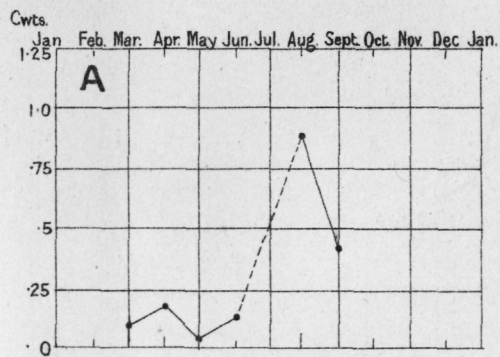
In the fishing grounds to the east of the Deep Water there is a great amount of fishing, as a considerable quantity of plaice can always be found; so that the records for F and J, the northern and middle areas, are almost complete and give continuous curves showing two periods of maximum amount and two of minimum, in spring and autumn respectively. It is interesting to compare these two with respect to the seasonal changes. The amounts for the first three months are higher in J than in F, and the spring maximum arrives a month earlier in this, the more southerly area. There is not so large a fall in the summer months in F as in J, but the fall from the autumn maximum to the winter minimum is much greater. It is .73 cwts. in F and .44 in J. In F the autumn maximum is greater than the spring maximum (the difference .16 is more than twice the probable difference .068). In J the reverse is the case. In F the January average is based on only one year's catch and is clearly unrepresentative. The fall from November is probably continuous till February or March. In J October and November are months of maximum, as the October averages are twice greater than the November ones, and twice less than these. The explanation of these differences between F and J probably lies in the fact that J lies nearer to the southern spawning grounds and is itself somewhat more of a spawning area than F (*see* Table VII.).

The curve for area M exhibits many irregularities. The main features shown by this curve are that the averages for the winter months are very high and that there is apparently a great scarcity of fish in this region in the months July, August and September. This latter fact is borne out more by the downward trend of the curve from March onwards and by the almost total absence of fishing in these three months than by the averages themselves, which are rendered quite invalid owing to the lack of a sufficient number of records. There is an increase in the amounts till November and then the curve fluctuates considerably. This may be due to the fact that this area covers a large extent of ground of which the northern portion has different characteristics from the southern, while the fishing was not distributed evenly over the two parts.

The Spawning of Plaice.

The information given by the fishermen in the small table of "Spawning Fish" at the foot of the Record forms has been tabulated with regard to plaice and reduced to the totals and percentages given in the annexed table. The fishermen are required to state whether the spawning fish are few, many or none, and whether large or medium sized. The lack of consistency in their methods of doing this, and the numerous occasions on which the sizes were undistinguished or mixed, made it impossible to tabulate all this

FIG 2. DIAGRAMS SHOWING FOR EACH AREA THE AVERAGE MONTHLY CATCH OF PLAICE IN CWTs. PER 6 HRS. FISHING.



detail, so we were obliged to give merely the total number of hauls in which spawning plaice were recorded. It may be mentioned, however, that in by far the largest proportion of the hauls the spawning plaice were entered as 'Few,' simply, and sometimes as 'Few, Large and Medium.' Out of a total number of 907 records 58 had "Many spawning plaice." Of these 4 were entered in November, 7 in December, 24 in January, and 23 in February.

The records cover three seasons of maturation and spawning, *i.e.* the months September to March in the years 1903-4, 1904-5, 1905-6. They all showed the same phenomenon, *i.e.*, a gradual increase in the number of spawning records till January, followed by a sharp fall, while the relative proportion of spawning records to hauls in each area was approximately the same year by year. Thus all the records could be combined into one table, which shows the sum of all the spawning records in the three Octobers, Novembers, &c., from which we obtain a fair representation of the actual fluctuations.

TABLE VII.—Showing for the three spawning seasons 1903-6 the monthly total number of hauls in each area in which spawning plaice are recorded, and the percentage which these constitute of the total number of hauls in each area.

Areas.		B.	C.	E.	F.	H.	J.	M.	All areas.
September	{ No. ...	—	1	4	2	1	2	—	10
	{ Percentage	—	[50]	2½	2	9	4½	—	3
October	{ No. ...	1	9	1	33	2	27	2	75
	{ Percentage	6	[61]	4	29	8	30	8	24
November	{ No. ...	—	5	2	44	29	52	24	156*
	{ Percentage	—	28	17	43	30	47	44	38
December	{ No. ...	—	—	4	8	125	11	32	180†
	{ Percentage	—	—	25	71	60	58	65	59
January	{ No. ...	—	—	5	4	159	32	100	300‡
	{ Percentage	—	—	83	25	72½	59	71	66
February	{ No. ...	—	—	7	3	106	31	31	178
	{ Percentage	—	—	32	16	58	38	44	47
March	{ No. ...	—	—	—	3	—	1	4	8
	{ Percentage	—	—	—	13	—	2	2½	3

* Including 13 hauls in November in which plaice are recorded "with large roes."

† Including 26 hauls in December in which plaice are recorded "with large roes."

‡ Including 1 haul in January in which plaice are recorded "with large roes."

There are one or two sources of error, which need to be mentioned and borne in mind when studying the table. The first is that one of the men records a considerably fewer number of hauls than the others, and there is reason to believe that on occasions he omits to record the spawning fish. The September and March records are made by one man alone, the former in 1903, and too much reliance cannot be placed on them, as we have a tendency to error in another direction, which is caused by an ambiguity in the use of the term "spawning fish" and the consequent inclusion among the records of plaice that are not actually spawning, but whose roes are ripe, and which are more or less ready to spawn. This distinction between 'maturing' and 'spawning' fish was probably not always in the fishermen's minds, and although they have in certain cases explicitly noted the fact that their entries referred to ripening rather than to actually spawning fish, it is probable that these do not exhaust the list. The cases mentioned were of 13 hauls in November, 26 in December, with one in January, in which "plaice with large roes" were recorded. If these are omitted the percentages for all areas in the months November and December become lowered to 35 per cent. and 51 per cent. respectively. Spent fish appear to have been ignored altogether. It would be safer therefore to regard the table as a summary of observations concerning maturation than concerning spawning in the strict sense of the term.

The percentage values given in the table are calculated from the total number of six hour periods of fishing in each area. These give the proportion of hauls in which spawning plaice are found and therefore describe the relative abundance of these fish in the different areas. The high values given for area C should be neglected in comparison

with the other areas, as very few hauls were made here and they cannot be taken as representative. No instances of spawning plaice were found in D or A, and only one in the other Northern area B.

It will be seen from the table that the greatest number of spawning plaice comes from area H. 56 per cent. of the total number of hauls in this area during the spawning season yielded spawning plaice; Area M comes next with a percentage of 38. Both these are Southern areas and thus we have confirmed the knowledge of the habits of spawning plaice which has been obtained from other sources,* viz., that they tend to congregate during the winter in the southern part of the Deep Water. The intermediate areas show spawning plaice in fair numbers and up to November these seem to exceed the amounts taken from H. After this the numbers of hauls in H and M are considerably above the others, which is probably due to the fact that the plaice have migrated further southwards.

Taking both the absolute number of spawning records (one record for each haul) and their percentage values as compared with the total amount of fishing, as a rough measure of the frequency of spawning fish, we see that in each of the chief spawning areas, F, H, J and M, and in all areas together the numbers increase gradually till January and then fall away rapidly till they practically cease at the end of February. January is apparently the height of the spawning season, and this is further confirmed by the fact that it is in this month that the hauls recording "many spawning fish" are found. These occur only in areas H and M which are the chief spawning grounds in this region.

General Conclusions.

A. Distribution.—The region investigated by these statistics is essentially a fishing ground for plaice. This being so, we have a rough guide to the movements of the plaice, by the amount of fishing that takes place in the different areas—the men going to fish where they know they can get the best stock.

It is found that plaice are very scarce on the shallow grounds off the English coasts—that they increase as we move eastwards, and that they are most numerous on the grounds nearest the continental coasts, the quantities caught decreasing as we proceed northwards and away from the coast.

We have found the following seasonal variations in the abundance of plaice in the different parts of this region :—

A, B and C.—In the northern areas the maximum abundance is found in summer and the minimum in winter, when the catches of plaice are so small that fishing becomes unprofitable.

H and M.—In the southern areas the maximum abundance occurs in winter and the minimum in summer.

F and J.—In the intermediate grounds between these two groups, on the other hand, there are two well defined maxima, occurring in the spring and autumn, with a fair stock of fish on these grounds throughout the year.

B. Migrations.—The observed changes in the seasonal abundance admit of easy explanation in view of the seasonal migrations, which have elsewhere been shown by the marking experiments to take place in this area.† The spring and autumn maxima on the intermediate grounds are probably caused by the stocks of fish migrating across them to the north and south respectively at these seasons.

The summer maximum in the north is probably caused by the spring immigration, reinforced throughout the summer by direct migrations from the Dutch coast, and the winter minimum by the autumn exodus: the winter maximum on the southern grounds is probably due to the southward migration of plaice for the purposes of spawning.

C. Spawning.—Spawning plaice are found in large numbers during the early part of the year. January especially is the month in which their occurrence is most frequent, while plaice found to be maturing are frequently recorded during the winter months. As H and M, the most southerly parts of this region, are the most important spawning grounds, there is some evidence that the increased catches made here in winter are largely due to the presence of spawning fish.

* Garstang. Trawling Investigations. *International Investigations, Mar. Biol. Assoc., Report I., 1905. Cd. 2670.*

† See Garstang. Report on Experiments with Marked Fish, 1902-3. *International Investigations, Mar. Biol. Assoc., Report I., 1905. Cd. 2670.*

B.—SOLES.

Introduction.

The records of the number of soles caught have been tabulated in exactly the same way as the plaice records ; that is to say, we have the average catch of soles, month by month, for the same period and for the same areas as in the case of plaice.

The way in which the catch of soles has been recorded, has been uniform throughout the period. The sizes are distinguished as large, medium and slips, and the numbers of *pairs* of soles of each kind are given. In the tables, however, all the averages are calculated as numbers of fish and not in pairs. The size distinctions are retained and the total number of fish at all sizes given, as well as those of the separate size groups. By "large" soles the fishermen mean those about 12 inches and over ; "medium" those from 8 or 9 inches to 12 inches, while "slips" or small soles are 8 inches or less in length. We find that the total number of soles caught is very small compared with that of plaice—yet they suffice to show the quantitative distribution of these fish as well as some of the seasonal changes.

Yearly Variations.

The first table (Table VIII) and the corresponding diagram (Fig. 3.) show the changes in the average catch per 6 hours' fishing for each year, when all the catches from the various areas are put together. The table gives, also, the total number caught by each fisherman and by all three together. As in the case of plaice, the records for 1903 being incomplete, figures for the whole year (January to December) have been estimated, and it is these estimated values that are plotted in the diagram. They are 10·5 large, 4·5 medium, 7·9 small and 22·9 all sizes. The best year for soles was 1903, in which year all sizes were considerably more numerous than in the other years, which do not fluctuate much. There is a small rise from 1904–5, followed by a slightly greater fall to 1906.

TABLE VIII.—Showing the total number of soles caught in each of the years 1903–6 and the yearly average catch per 6 hours' fishing taken by each skipper.

		Skipper.	Total number of Soles.				Average number of Soles per 6 hours' fishing.			
			Large.	Medium.	Small.	All Sizes.	Large.	Medium.	Small.	All Sizes.
1903—April–December.	i		3533	1220	1914	6667	11·9	4·1	6·5	22·5
	ii		2778	1169	2622	6569	7·5	3·1	7·0	17·6
	iii		5318	2434	3518	11270	16·2	7·4	10·7	34·4
	All		11629	4823	8034	24486	11·7	4·8	8·1	24·6
1904	i		4131	1288	2502	7921	10·5	3·3	6·4	20·2
	ii		3225	1490	2103	6818	6·0	2·8	3·9	12·7
	iii		3859	2147	3784	9790	7·4	4·1	7·2	18·7
	All		11215	4925	8389	24529	7·7	3·4	5·8	16·9
1905	i		3912	994	1852	6758	9·1	2·3	4·3	15·7
	ii		3461	1421	1733	6615	7·0	2·9	3·5	13·4
	iii		4117	2330	3988	10435	8·9	5·0	8·6	22·5
	All		11490	4745	7573	23808	8·3	3·4	5·5	17·2
1906	i		4131	1084	2058	7273	8·6	2·2	4·3	15·1
	ii		3397	1144	1755	6296	7·2	2·4	3·7	13·3
	iii		3700	2398	3312	9410	7·4	4·8	6·6	18·9
	All		11228	4626	7125	22979	7·7	3·2	4·9	15·8

The numbers of large soles fluctuate the most—the greater part of the large fall in 1904 being due to a decrease in the number of large fish while the rise in 1905 is in large soles alone. The numbers of medium soles are practically stationary after 1904, and in the average for small soles or "slips," there is a continuous but very slight fall. When we compare one fisherman's averages with another's, we have no evidence of any real change in the stock of fish in this period except between the years 1903 and 1904, when there is apparently a decline.

It should be remembered, however (cf. Table II.), that in this year 1904, the areas D and A, which are known to be far the most productive, have the least representative number of hours' fishing, while the eastern areas J and M are more represented in the last

three years, and these are known to be poorly populated areas. On the other hand, F also is ill-populated and the fishing there decreases from 1903–1906, so that it is probable the distribution of fishing will not affect the averages very much—if at all, they would be made slightly more equal by the fishing being distributed equally in the different years.

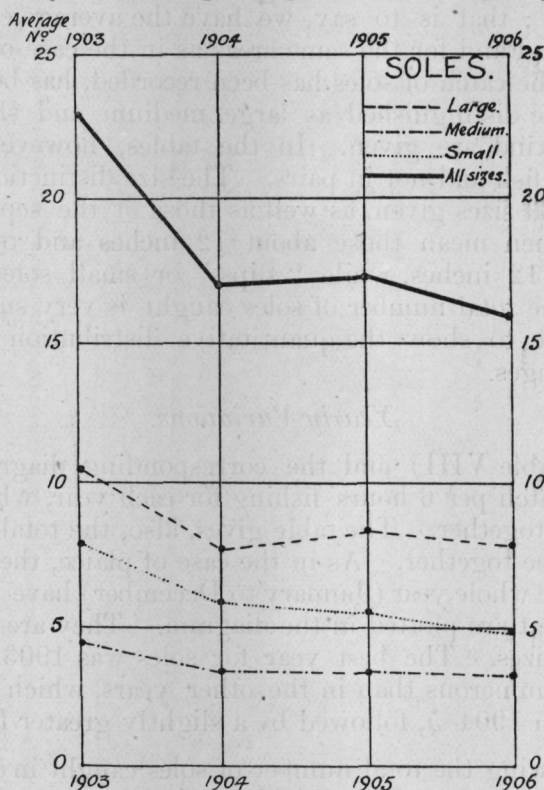


FIG. 3.—CURVES showing the annual average number of soles taken per 6 hours' fishing.

The diagram also shows the proportion of the catch formed by the large, medium and small groups. Large fish are the most abundant and medium-sized fish the least, while the number of small soles comes nearly half-way between the other groups. In almost all the areas we find that the large soles considerably exceed in numbers the small and medium-sized fish. They form from 45 per cent. to 49 per cent. of the total number caught.

Distribution and Seasonal Variations.

Table IX. and the diagrams illustrating the monthly abundance of soles in the several areas (Fig. 4)* need to be studied in the same way as the Plaice tables, care being taken to notice which averages are reliable and which, owing to a scarcity of the number of hauls, are not. As before, the curves represent the monthly averages formed by adding together the total catch of the four years in each month, and dividing by the corresponding number of hauls of 6 hours' duration.

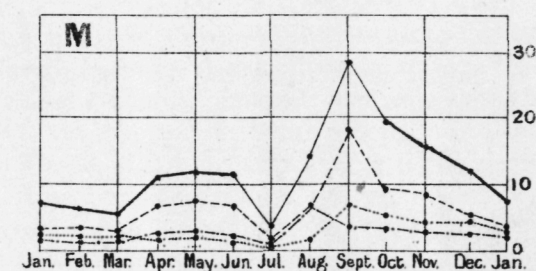
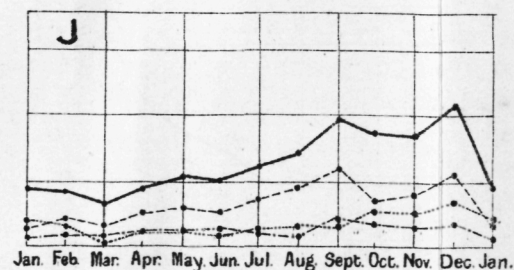
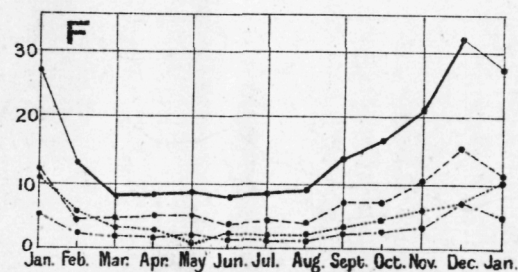
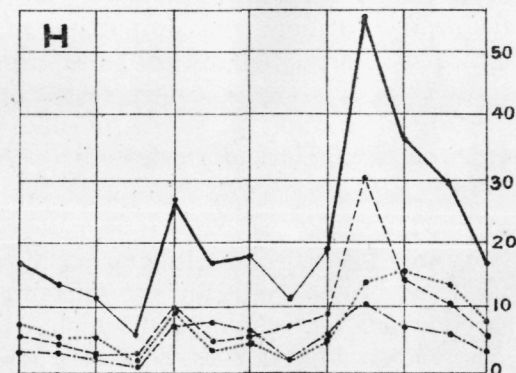
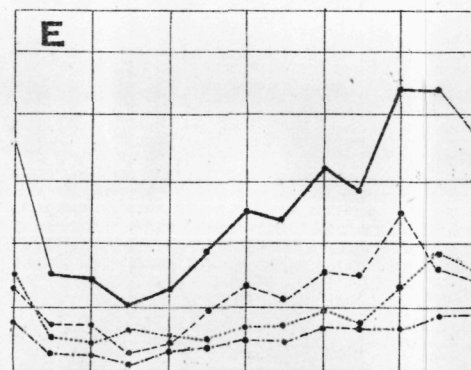
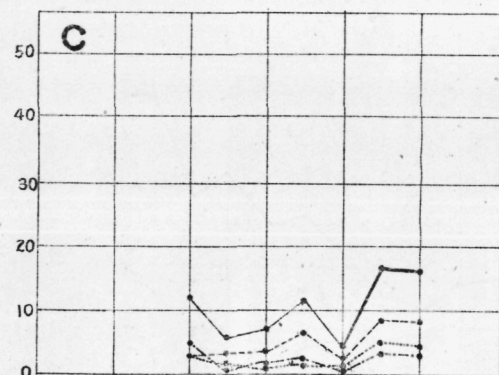
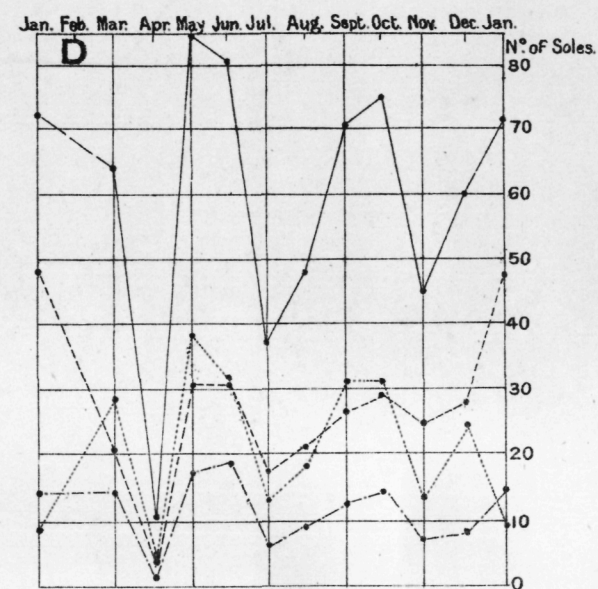
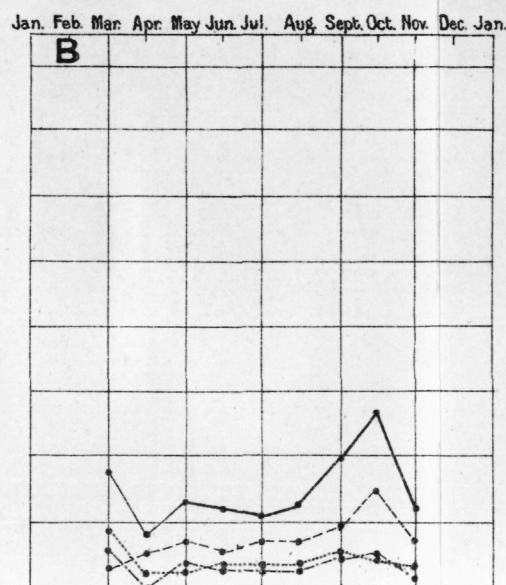
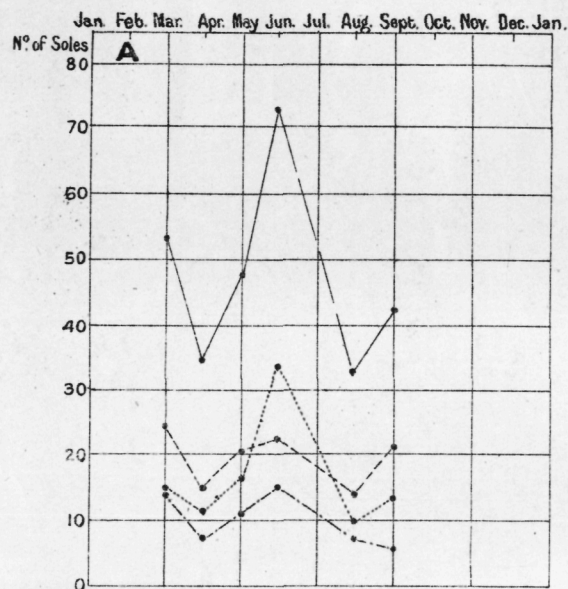
One of the most striking features of the diagrams is the fact that the curves for the different size groups move in nearly parallel directions, *i.e.*, their fluctuations are of the same nature and occur at the same time. The large, medium and small groups have their maxima and minima at coincident periods, and rise and fall together between these.

The exceptions to this rule can easily be accounted for, since it will generally be found that these averages are the ones considered unreliable for the reasons mentioned above. It is therefore evident that the main causes producing the migrations of soles affect all sizes. The thick lines in the diagrams represent the average number of soles of all sizes and give a good idea of their general movement.

Comparing their numerical distribution in the various areas, we see that soles are by far the most abundant in area D, the Lowestoft Flats. They are also numerous on the grounds to the north of this (Cromer Knoll, area A), but the absence of fishing here in the autumn and winter months, on account of the scarcity of other species of fish (mainly plaice) leaves us without information as to the abundance of soles during these months. By contrast with these western grounds, the easterly areas C, F, J and M, all show a great scarcity of fish, the total of all sizes seldom exceeding 15 or 20 per haul. It is to be noticed too, in these areas that as we move further southwards the fish get scarcer. The

* On the curve representing catches of all sizes, broken lines are used to join two alternate month's averages, when there is no record in the intermediate month, and thin lines are used to join up the averages of months, which are considered unreliable.

FIG 4. DIAGRAMS SHOWING FOR EACH AERA THE AVERAGE MONTHLY CATCH OF SOLES, IN NUMBERS OF FISH PER 6 HOURS FISHING LARGE, MEDIUM AND SMALL-SIZED FISH BEING DISTINGUISHED.



—•— ALL SIZES - - - - - MEDIUM SMALL

average of the 12 monthly averages for the areas F, J and M, are respectively 14.4, 13.2 and 12.2. In the case of plaice we found precisely the opposite condition. Indeed, it seems evident from a mere glance at the two sets of diagrams that where plaice are most abundant, the soles are least abundant (as in M), and *vice versa*, an abundance of soles, (as in D and A) is accompanied by a scarcity of plaice. The two deep water areas, H and E, exhibit the same phenomenon. E, the more northerly, has an average for the year of 25.3, and H of 19.8 soles per 6 hours' fishing. Of these 11.7 in area E, and 9.0 in area H, are large soles, both being about 45 per cent. of the total number. Compared with the other areas regularly fished by these men, these areas seem more productive of soles of a good marketable size.

In the northern areas, A, B, and C, the records are too few to give any certain information regarding periods of maximum and minimum abundance. The quantities of soles decrease considerably as we move eastwards, the average numbers caught in C being very small. There are indications of an increase in May and June in area A, and in October in B and C, the former increase being mostly due to a considerable influx of "slips."

The curve illustrating the abundance of soles in area D is of a very fluctuating character owing to the absence of a sufficient number of records. Neglecting the cusp in April, which is the average of only two hauls, we see that there is apparently an increase in the number of fish in the spring culminating in a high maximum in May and June. There is a big drop in the summer months, and then the curve rises again till October. The minimum periods are presumably in the summer and winter seasons.

Taking the average of the 12 months, we find that out of every 59 soles caught 25 are large and 22 small, so that the number of small soles is practically equal to that of the large soles in this area, whereas in the other cases, they are considerably exceeded by the large fish. In this respect we may compare area A, where the same preponderance of slips occurs, clearly indicating proximity of nursery grounds, which have been found by trawling experiments and distribution of eggs, to be on the English Coast.*

Illustrating the fluctuations of the catch in area E, we have a fairly smooth, continuous curve showing a scarcity in the total numbers caught in March, April and May, at the period when the numbers in the adjacent area D are rapidly increasing—after this, except for the slight fall from September to October, there is a *slow and steady* rise to a high maximum in November and December. The curve then falls sharply from this winter maximum to the spring minimum in April.

For the adjacent area H we have a curve with two apparently very sharp cusps in May and October; an examination of the table shows that the great excess of these months over the ones before and after them is due to the unusually high averages in the year 1903. Without these there is some slight evidence of a maximum in May, but an October maximum is not established. The November averages are all high, and this month is just as likely to be the maximum as October. December is significantly less than November, and so also is the fall to January a significant one. The minima appear to be in March or April and in August. We notice that in this ground as in the other deep water area E, the autumn averages are considerably higher than those of the rest of the year, while the spring values are very low. This great rise in these two curves in the autumn and the corresponding depression in spring shows that the tendency of soles of all sizes, but more especially of large soles, is to move into deep water as the cold weather comes on, and to leave it in early spring. Trawling investigations, later than those described by Garstang in his first Report, show that the larger soles congregate for spawning purposes in special localities in shallow water, especially in May. This probably accounts for the diminution observed in these deep water areas in the spring.

The fluctuations in area H are very similar to those in the adjacent area M, only in this latter area, which is shallower and more easterly, the quantities are very much smaller. There is the same fall from the autumn maximum to the spring minimum, both of which, however, occur a month earlier, *i.e.* if we are justified in assuming that September is the month of greatest abundance in this area, a fact which seems probable, but is not certain. It is noticeable that the maxima in M, H and E, occur in succession, being found later as we get further north. Similarly when we compare F and J with M, we have the same order. The spring and summer averages in M are low, and if we neglect the August average of only 4 hauls, there appears to be an increase after the spring till the autumn maximum, with no definite evidence of a second maximum period. The increase from March to April is sudden, and corresponds to the approach of the spawning season.

* Garstang. Trawling Investigations. *International Investigations, Mar, Biol. Assoc., Report I.* [1905]. Cd. 2670.

December appears to be the month of greatest abundance in both the eastern areas F and J, although in the latter each of the months September, October and November, have fairly high and nearly equal averages, so that the increase in the number of soles begins earlier and extends over a longer period in this area than in F. There is greater difference between the greatest and least averages in F than in J, in which area we notice that there is very little fluctuation in amount. Throughout the greater part of the year these areas seem to maintain a low but very regular stock of soles, which is augmented for a short time only in winter.

The Spawning of Soles.

In the case of soles the information supplied by the fishermen of occurrences of spawning individuals was far less regular and complete than that for plaice, so that we are not able to glean much information from the table appended (Table X.). In fact,

TABLE X.—Showing the monthly total number of hauls in each area in which soles are recorded by skipper (ii.) as spawning, and the percentage which these constitute of the total number of his hauls in each area.

Areas.	A.	B.	D.	E.	F.	H.	J.	M.	All areas.
January ... { No. ...	—	—	—	—	—	6	4	15	25
January ... { Percentage	—	—	—	—	—	17	40	26	24
February { No. ...	—	—	—	0	2	7	3	15	27
February { Percentage	—	—	—	0	100	18	11½	34	26
March ... { No. ...	5	0	2	1	2	—	6	17	33
March ... { Percentage	83	0	67	25	33	—	46	39	43
April ... { No. ...	3	—	—	0	2	1	30	26	62
April ... { Percentage	100	—	—	0	13	50	53	48	49
May ... { No. ...	—	—	—	0	3	1	24	17	45
May ... { Percentage	—	—	—	0	43	25	41	33	36
June ... { No. ...	—	—	—	2	4	0	2	1	9
June ... { Percentage	—	—	—	12½	11	0	7	6	9
July ... { No. ...	—	1	4	4	2	0	0	0	11
July ... { Percentage	—	100	36	5	8	0	0	0	8½
August ... { No. ...	—	0	—	4	1	1	0	0	6
August ... { Percentage	—	0	—	4½	2	20	0	0	4
September { No. ...	—	—	0	1	0	0	0	—	1
September { Percentage	—	—	0	3	0	0	0	—	1
November { No. ...	—	—	0	0	3	0	3	3	9
November { Percentage	—	—	0	0	11	0	9	12½	8
December { No. ...	—	—	—	1	3	12	5	9	30
December { Percentage	—	—	—	33	37½	27	55½	16	25

there was only one fisherman who recorded the occurrences of spawning soles throughout the whole period. The others only mentioned them in 15 hauls altogether, and these were made in the first two years. For purpose of tabulation it was therefore necessary to take this fisherman's records alone, and to calculate the percentage number of occurrences on his total number of hauls in each area in each month. The totals are the combined totals in each month from all the years. In comparing the months, we must remember that only three years are represented in the January to March totals and four in the rest, so that the former are too low in comparison. The material is too scanty to permit any accurate interpolation to be made to correct this, but the percentage values will give a better indication of the comparative abundance. We can draw no definite conclusions as to the geographical distribution of spawning soles. They are found occurring in all areas and perhaps less often in the deep water than in the other areas. The table shows that of the areas F, J and M, in which spawning soles are constantly found, J has the greater share. It is unfortunate, for this inquiry, that this man has not had more fishing in areas A and D, for there are some indications in the table that these contain a large number of spawning soles. In April they were present in all three hauls he made in area A, and in March in five out of six hauls. In D, two out of three hauls contained spawning soles,

but we have no information as to the proportion in April, as this particular fisherman was not fishing here during this month; but one of the other skippers, by whom was made a record of one voyage in the northern part of this area in May, 1903, records a considerable number of spawning soles. The evidence therefore suggests the conclusion that these two shallow areas are amongst the best spawning grounds for soles in this region. The percentage values given in the last column affords a rough means of comparing the abundance in each month. April has considerably higher values than the months preceding and following it, and as the values fall away on each side of this month it may be taken as the height of the spawning season in this region.

The skipper whose records these are, informs us that "spawning" meant "with roe in" and not necessarily in the condition of actually spawning, and in 1906 several instances occur in the months preceding April, in which they are recorded as such, and we may take it that he means "maturing" in most cases. Owing to this, the numbers of really spawning soles recorded from November to March are considerably augmented, and we may gather that they are not nearly so frequently found in the winter months as one would be led to believe from a first glance at the table.

The quantities of soles found spawning are generally entered in the records as "few," sometimes the numbers are given. In such cases there are from 1-5 spawning soles in each haul. In April the numbers rise considerably to as many as from 10-14 in each haul, which further confirms the fact that they are most frequent in this month.

General Conclusions.

A. Distribution.—The number of soles caught in the Flemish Bight is not very great. They show the following seasonal and geographical distribution. They are far more numerous on the English than on the continental side, and increase in numbers from east to west. The maximum catch is over 80 (per six hours' fishing) on the western side, and only 30 on the eastern side of the deep water. Moreover, they also become numerically greater as we move northwards.

As a rule large soles predominate in the catches; over the whole area they form nearly one half of the total number caught. Slips, however, form a large proportion of the catch in A and D, the two grounds nearest the English coast, where the sole nursery grounds are to be found. Their maximum abundance is found in spring in these two coastal grounds. In all other areas their period of maximum abundance is found in autumn and winter, and their minimum abundance in spring.*

B. Migrations.—The evidence on this point is by no means conclusive, and we can only offer suggestions. These, gathered as they are from figures which, in several instances are unsatisfactory, yet are put forward as an attempt to offer some hypothetical explanation of the movements of soles, to be corroborated or laid aside by the evidence of further statistics.

There is probably a movement northwards through this region from September and throughout the colder months, for we have seen that in area M the soles are most abundant in September, in H and J in October, while in E and F November and December seem to be the best months. Perhaps, too, there is a movement between the deep water and the shallow flats off the English coast, the numbers in the latter area being augmented in early spring by a migration from the deeper water. In the cold months the eastern and middle areas all show an increase which would point to an augmentation in the stock from some grounds lying outside the regions investigated, perhaps from the shallower coastal waters where they have been residing during the earlier part of the year for the purpose of spawning.

It should be noticed too that these increases, though participated in by all three sizes of soles, yet are much more marked among the large soles, showing that a larger proportion of these migrate and cause the greater part of the increase in any ground. The exceptions to this rule are those areas A and D, which, being in close proximity to the English nursery grounds, are more affected by the immigration of slips.

C. Spawning.—As far as one can conclude from the scanty figures at our disposal, spawning fish are found frequently in March, April, and May, with a few occurrences in the months preceding. The shallower grounds, perhaps especially those on the English coast, have a larger frequency of spawning fish than the deeper water.

In conclusion, it is evident that there is room for far more investigation into the habits and movements of this species, and especially into the causes of their movements, which knowledge is necessary to fully explain the phenomena shown by these records.

* Garstang. Trawling Investigations.—Area V. Flemish Bight.—*International Investigations. Mar. Biol. Assoc. Report I. 1905, Cd. 2760.*

APPENDIX.

FORMS ON WHICH THE RECORDS WERE COLLECTED.

A.—Forms used by Skippers in recording single hauls up to April 1904.

MARINE BIOLOGICAL ASSOCIATION OF THE UNITED KINGDOM, SURVEY OF TRAWLING GROUNDS.

Date _____ Vessel _____ of _____

Name of Ground

Position or bearings

Depth	Nature of bottom
-------	------------------

Hour when shot	How long towed	Hours.
----------------	----------------	--------

Fish.				Number of	Fish.				Number of.
Plaice ...	{	Large ...	...	Fish.	Cod ...	{	Large ...	...	Fish.
		Medium	...	Trunks.			Medium	...	Trunks.
		Small...	...	Do.			Codling	...	Do.
Flounders	...	...	...	Trunks.	Gurnard	...	...	...	Trunks.
Dabs	...	...	...	Do.	Latchets (Tubs)	...	...	...
Lemons	...	...	...		Ling	...	...	...
Turbot ...	{	Large ...	...	Fish.	Haddock	{	Large ...	...	Trunks.
		Small...	...	Do.			Small ..	...	Do.
Brill	...	...	...	Fish.	Whiting	...	...	...	Trunks.
Soles	{	Large ...	...	Pairs.	Skate	...	...	...
		Medium	...	Do.	Roker	...	...	...
		Slips	...	Do.					

REFUSE AND SUNDRIES.

Kind.				Quantity.	Kind.				Quantity.
Dog Fish		Squid	...	...	...
Star Fish		Whelks	...	...	...

SPAWNING FISH.

Plaice Cod	Turbot Whiting	Sole Haddock
---------------	-------------------	-----------------

Signed _____ Master. _____ Date _____

B.—Forms used by Skippers in recording single hauls, since April, 1904.

MARINE BIOLOGICAL ASSOCIATION OF THE UNITED KINGDOM, SURVEY OF TRAWLING GROUNDS.

Date

Vessel

of

Name of Ground

Position when trawl shot

Depth

Soil

Hour when shot

How long towed

Hours.

Course

Wind

Sea

Fish.				Number of.		Fish.				Number of.					
Plaice ...	{	Large ...	...	Baskets.	Do.	Cod ...	{	Large ...	...	Score.	Do.		
		Medium					Medium			Baskets.			
		Small ...	...					Codling ...	...					
Witches ...	...	...	...	Baskets.	Do.	Gurnard ...	...	...	...	Baskets.	Do.
Dabs ...	...	...	...	Do.	Do.	Latchets (Tubs) ...	...	...	...	Do.	Score.
Lemons ...	...	...	...	Do.	Do.	Ling ...	...	...	...	Do.	Score.
Turbot ...	{	Large ...	...	Fish.	Do.	Haddock	{	Large ...	...	Baskets.	Do.		
		Small ...	...					Small ...	...					
Brill ...	...	...	...	Fish.	Whiting ...	...	...	...	...	Baskets.	
Soles ...	{	Large ...	...	Pairs.	Do.	Skate ...	...	...	...	Score.	Do.
		Medium									Roker
		Slips									Dog Fish

NOTE.—In cases when the fish are less than a basket-full state whether $\frac{1}{4}$, $\frac{1}{2}$, or $\frac{3}{4}$ basket. If less than $\frac{1}{4}$ basket (or Score), state the actual number, and cross out the word "basket" (or "score").

SPAWNING FISH.

State whether few, many or none, and whether large or medium-sized.

Plaice	Turbot	Sole
Cod	Whiting	Haddock

Signed

Master.

Date

C.—Forms used by Skippers in recording result of whole voyage.

MARINE BIOLOGICAL ASSOCIATION OF THE UNITED KINGDOM, SURVEY OF TRAWLING GROUNDS.

SUMMARY OF VOYAGE.

Port of Departure

Date

„ Arrival

Date

Number of hauls omitted (if any)

General result of voyage (Good, Moderate, or Bad).

TOTAL FISH LANDED.

(State number of boxes, scores, &c., in each case.)

Fish.		Quantity.	Fish.		Quantity.
Plaice ...	{ Large...	...	Cod ...	{ Large...	...
	{ Medium	...		{ Medium	...
	{ Small...	...		{ Codling	...
Witches ..	...	...	Gurnard	...	...
Dabs ...	...	...	Latchetts (Tubs)	...	...
Lemons ...	...	...	Ling ...	...	...
Turbot ...	{ Large...	...	Haddock	{ Large...	...
	{ Small...	...		{ Small...	...
Brill ...	...	...	Whiting	...	...
Soles ...	{ Large...	...	Skate ...	...	...
	{ Medium	...	Roker ...	...	...
	{ Slips ...	...		

Date

Vessel

Signed

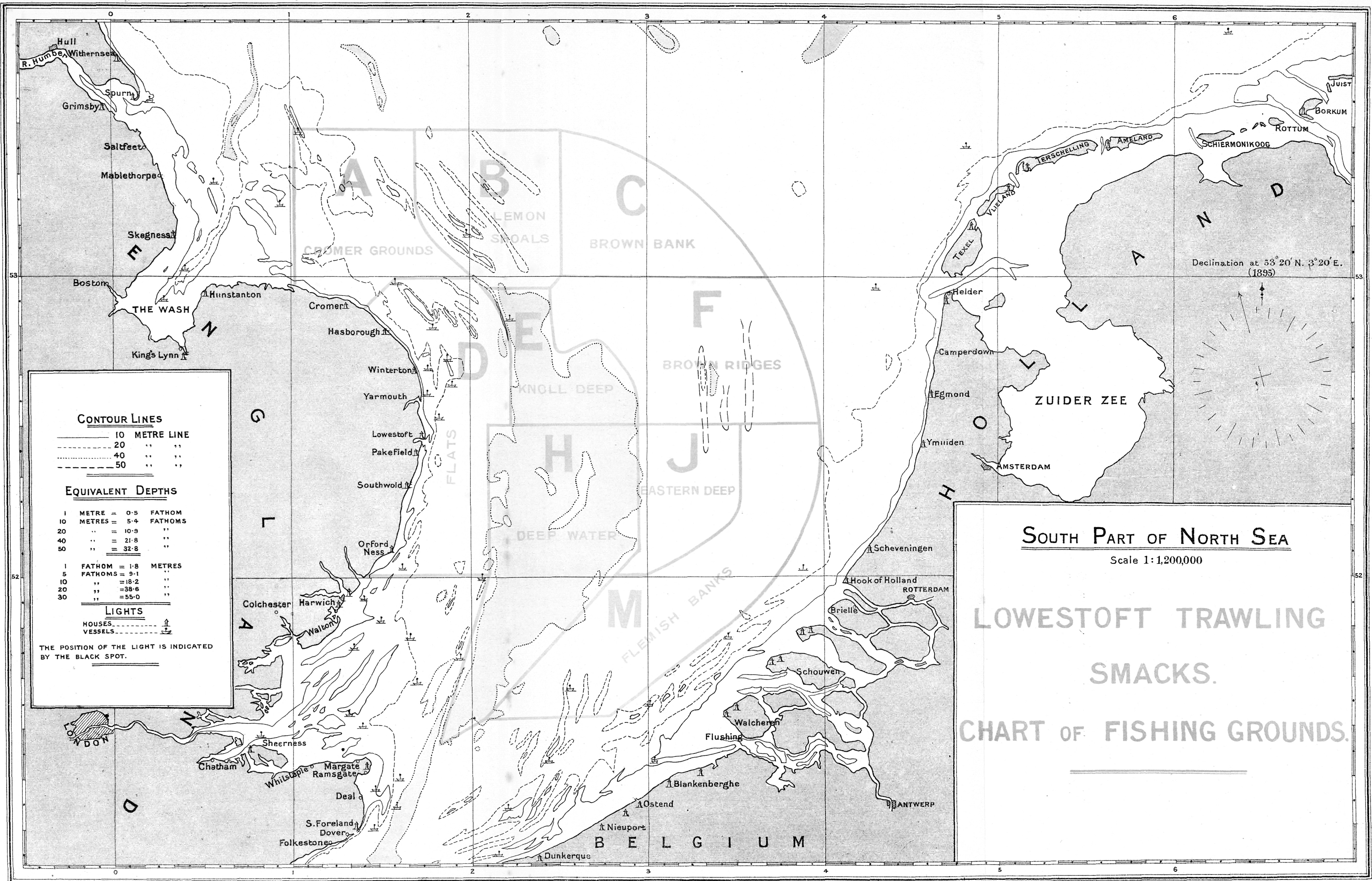
Master.

To face page 108.

TABLE IX.—SHOWING for each area the Monthly Average Number of Soles caught per six hours' fishing; large (L.), medium (M.), and small fish (S.) being distinguished. The monthly total number of hours' fishing in each area is given as an index number.

[illegible]

N.B.—In this table all fractions of an hour in the index numbers have been omitted, the unit figure being raised by 1 when the fraction was $\frac{1}{2}$. The total number of hours in the last line of each group is the correct total and not the total of the figures printed.



SOUTH PART OF NORTH SEA
 Scale 1:1,200,000

**LOWESTOFT TRAWLING
 SMACKS.**

CHART OF FISHING GROUNDS.